HEIDENHAIN

Technical Information

Application of Linear Encoders on Machine Tools

The requirements facing industrial production of mechanical parts are steadily growing. Rising cost pressure is driving a trend toward dynamic machine tools that produce parts economically with very high accuracy even in small batches. The use of linear encoders to ascertain the slide position– also called "closed-loop control"–permits accuracy from the first to the last part. The effects of the feed mechanism, such as a difference weight of workpiece or the expansion of the recirculating ball screw, have no influence on the machining result and therefore on the accuracy of the machine.

If the machine operates in a so-called "semiclosed loop," the table position is measured through the pitch of the recirculating ball screw and the angular position of the motor encoder. Changes in the feed mechanism, such as thermal expansion, cannot be detected in the closed loop. At higher traversing speeds, however, the ball screw becomes significantly warmer. (Figure 1) illustrates such heating with a thermal camera. The inhomogeneous temperature distribution with temperature peaks of up to 50.5°C is clearly visible. Positioning error up to 200 µm within a short time is unavoidable and cannot be compensated because of the unknown distribution curve.

The test setup shown in Fig. 2 illustrates the effects on the accuracy in the production of 300 parts. One workpiece with three holes, 2 mm deep, and the corresponding outside contour was machined. After 30 more workpieces were "machined" without tool contact, machining was repeated with 2 mm further infeed in the Z direction. This machining sequence was repeated to simulate the production of 300 individual parts.

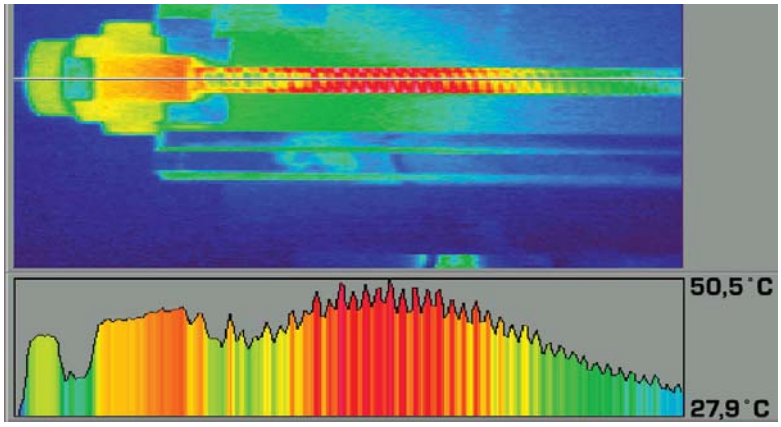

Figure 1: Thermal behavior of a recirculating ball screw

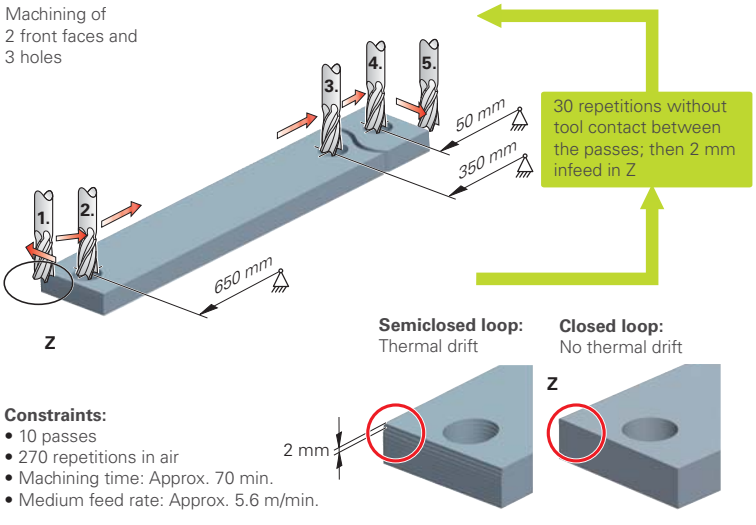

Figure 2: Effect of drive accuracy on series production

The workpieces show a considerable difference in the machining result of semiclosed loop control in comparison with that of a closed loop control. The deviations from the desired position are up to 200 µm. In contrast, the workpieces from machines with linear encoders provide the correct contour to within a few micrometers. (Fig. 3) The use of linear encoders therefore permits accuracy from the very first part without protracted run-in cycles. Of course, this also applies for mold making. If, for example, two mold halves are machined, then form deviations due to machine error normally require extensive rework.

This basic consideration applies both for linear and rotary axes. Here, too, positions can be measured with a speed-reduction mechanism connected to a rotary encoder on the motor, or with a highly accurate angle encoder on the machine axis, whereby angle encoders achieve significantly higher accuracy grades and reproducibility.

Linear encoders in various mechanical designs

Machine tools are usually equipped with sealed linear encoders, which are available in two designs.

The 100 series (with large cross section) is available up to a measuring length of 4240 mm. By fastening it every 200 mm with the machine base, a very high reliability is achieved against vibration conducted from outside. The 400 series (with small cross section) permits measuring lengths up to 2040 mm and is used primarily where installation space is limited. The fundamental design of the encoders is identical for both series.

A light source transmits light through the glass scale. The high-accuracy DIADUR graduation on the glass produces a precise pattern on the detector (photoelements), which is converted by the integrated electronics into electrical signals. With linear encoders for machine tools, the

Figure 3: Deviation between hole patterns in series production

Figure 4: Full-size and slimline linear encoders

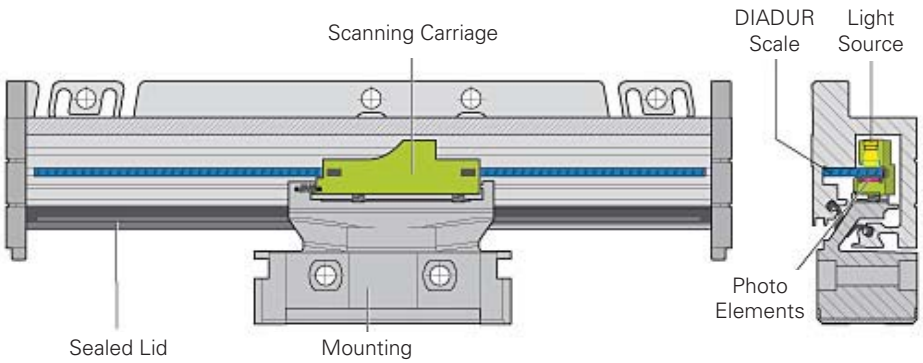

Figure 5 : Principle of design

detectors function exclusively according to what is known as the single-field principle. These detectors, opto-ASICs developed by HEIDENHAIN, are optimized for application in machine tools. They are characterized by high tolerance to contamination and EMC interference. This modern sensor technology is the basic prerequisite for very high reliability together with consistent signal stability. The housing protects the optics from heavy contamination and allows itself to be fastened to the machine base. The elastic sealing lips close the slot required for movement almost completely. In many cases, these measures do not suffice to ensure reliable operation. Under extreme exposure to liquid or condensation, the use of clean compressed air has proven to ensure reliability for many years of operation. A coupling between scanning carriage and mounting base permit the +/- 0.3 mm mounting tolerance to the machine components without impairing the accuracy of the encoder.

In the machine tool sector, too, the share of linear axes with direct drive is steadily increasing. This has been driving the continuously increasing demands on measuring technology with regard to signal quality and neutrality in the control loop. Besides small signal periods, a low position error within the period is also required in order to attain the required bandwidth in the closed loop. The absolute LC linear encoders with single-field scanning attain a max. error within the signal period of +/- 20 nm and therefore place no limit for the control bandwidth. Absolute measuring technology significantly facilitates finding the commutation angle after the machine tool is switched on, and allows simple implementation of feed axes with direct drive.

Mounting the encoders

If the use of linear encoders is considered early in the design phase, fast and reliable mounting in only a few minutes is possible. For example, it allows the required alignment of the encoder to the machine guideway through milled stop edges.

Of course, pins can also be used to align the encoders. For the absolute linear encoders of the 400 series there are accessory "pins with clamping elements" that ensure a reliable connection of the scale with the machine base. They are recommended for measuring lengths of 640 mm and more. At 1240 mm measuring length or longer, the clamping elements or a mounting spar must be used in order to ensure the required stability of the encoder perpendicular to the measuring direction.

The clamping elements have two advantages over the use of mounting spars. First, they can reduce cost, and second, they do not change the basic mounting conditions. It is therefore easy to implement a modular design with variable measuring length.

Summary

A decisive factor for the productivity of a machine tool, besides accuracy (can I use this equipment to manufacture this part in a reliable process), is the availability of the equipment. High productivity with consistently high part quality is most easily achieved with linear or angle encoders. Today, their application is considered standard, not only on universal machines, but also on production machines. They are supported with numerous aids, beginning with 3-D models for simpler machine design, to special mounting accessories, fast and reliable mounting, and electrical testing equipment for initial servicing.

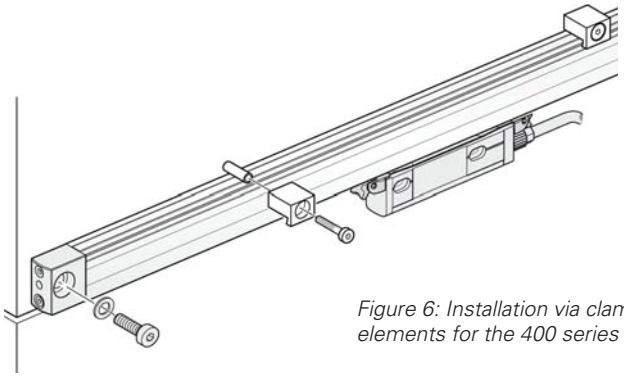

Figure 6: Installation via clamping elements for the 400 series

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